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Infiltration Characteristics of Organic Amended Soils

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Abstract- The infiltration characteristics of organic amended soil were studied for soils amended with cow dung (CM) and poultry litter (PM). The aim was to determine the effect of these amendments on the infiltration characteristics of the soil. A field size of 200 m^2 was divided into three strips, 50 kg each of Cow dung and poultry litter was applied into the first and third strip and the middle strip served as control. Soil samples were taken from each strip for soil's physical property determination, one week after manure application infiltration runs were made using the double ring infiltrometer from six points on each strip, and the tests were repeated three weeks and six weeks after manure application. Bulk density of CM and PM reduced by 15.5% and 33.2% respectively, the CM strip increased infiltration rate by 60 % relative to the Control while the PM strip increased infiltration rate by 29 %. T-test showed a high significant difference between the control and the amended strips, CM and PM strip increased cumulative infiltration depth by 61.4 % and 48.1%.

Keywords: *poultry litters, cow dung.*

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Infiltration Characteristics of Organic Amended Soils

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I. Introduction

The use of organic manure in place of inorganic fertilizers in crop production by local farmers in Nigeria is increasing due to the high cost and scarcity of mineral fertilizers. Soils in which organic materials are incorporated are termed organic amended soils (Katsumi and Khan, 2012; Armin *et al.,* 2013; Ayeni and Adetunji, 2010). When soils are amended, water infiltration rate is affected amongst other physical properties. Water infiltration is the process of water movement from the ground surface into the soil and it is an important component in the hydrological cycle (Ajayi, 2015; Gana, 2011; Haghiabi*et al*., 2011).

When rainfall or irrigation soaks into the soil, a certain amount of the unfiltered water is temporally retained in the soil pores by capillary action and, if not quickly taken up by roots, gradually percolates downward from the root zone base to the water table at a rate which is equal to the constant infiltration rate or the hydraulic conductivity of the root zone layer. The amount of water retained in the topsoil is affected by the amount of organic matter content, the size, shape and arrangement of mineral particles (Gupta and Gupta, 2008).

Infiltration has received attention from soil and water scientists/engineers because of the fundamental role of infiltration characteristics in land-surface and subsurface hydrology, irrigation and agriculture. Infiltration characteristics of soils can be quantified by direct measurement on the field and/or when field infiltration data are fitted mathematically to infiltration models (Oku and Aiyelari, 2011). Lili*et al.* (2008) reviewed the commonly used direct methods for measuring soil infiltration which include: single ring and double ring infiltrometers, mariotte-double ring infiltrometer, disc permeameter, rainfall simulator, runoff-on-ponding, runoff-on-out and linear source methods. The results obtained from field infiltration test and soil analysis are used for infiltration modelling. There is a dearth of standard infiltration characteristics of organic amended soils so that they can easily be applied in irrigation and drainage systems design and management (Gana, 2011; Stanley 2010).

The aim of this paper is to determine the effect of cow manure (CM) and poultry manure (PM) on the infiltration characteristics of the experimental site and also to use four common water infiltration modelsto predict and compare field measured values with those simulated.

II. Materials and Methods

a) *Site Location and Treatments*

The study was carried out at the Department of Agricultural Engineering experimental field, Samaru, Zaria, Nigeria. Zaria is located on latitude 11° 11'N and longitude 07° 38'E, at an altitude of about 667m above sea level.

An area of 200 m^2 (20 × 10m) was divided into three strips labeled CM, CT and PM, to carry out infiltration tests. Each strip was 40m^2 (20 × 2m) and50 kg each of cow dung and poultry litter was added to the CM and PM strip, respectively. The middle strip was left bare (without any amendment) as the control strip (CT).

The manure was applied in the existing furrows in the respective strip and was then plowed using animal drawn mold board plow and harrowed using a spike tooth harrow to mix the amended portion with the manure thoroughly to a depth of 20cm.Three soil samples were collected from each strip at depths of 0-15 cm and 15-30 cm using Core Samplers of 5 cm diameter and 6 cm height to collect soil samples.

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b) Infiltration measurement and characteristics

The double ring infiltrometer method was used for the infiltration measurement. The infiltrometer consisted of two rings, outer ring of 40 cm diameter and 40 cm height, and the inner ring 30 cm diameter and 40 cm height. Both rings were hammered 15 cm into the soil with a plank to protect the surface of the ring from damage during hammering.

The test started by pouring water into the inner ring to an appropriate depth and at the same time, adding water to the space between the two rings to the same depth as quickly as possible. The time when the test began was recorded and the water level on the measuring rod was noted. After 3 minutes, the drop in water level in the inner ring was recorded on the measuring rod and water added to bring the level back to approximately the original level at the start of the test. The water level outside the ring was maintained similar to the one inside.

The test was repeated one, three and six weeks after the incorporation of the manure and six infiltration measurements were carried out per test. Each infiltration test lasted 4 hours with cumulative time intervals: 3, 5, 10, 20, 30, 45, 60, 90, 120, 150, 180, 210 and 240 minutes. The cumulative infiltration depth at the elapsed time was recorded. Using the data generated from a total of 36 infiltration runs (12 runs per treatment), cumulative infiltration and infiltration rates were computed for the soil of the experimental site under the tested land management systems. Curve fitting was carried out using four models:Kostiakov (1932), modified Kostiakov (Michael, 1978), Kostiakov-Lewis (1982) and Philip (1957) infiltration models by regression (Table 1).

Table 1: Equations and fitting parameters of the four models tested

	Model Name	Infiltration equation	Fitting parameters
1	Kostiakov (1932)	$I = kt^a$	*k* and a
2	Modified Kostiakov (1978)	$I = k_1 t^{a_1} + b$	k_1, a_1 and *b*
3	Philip (1957)	$I = S\sqrt{t} + At$	S and A
4	Kostiakov-Lewis (1982)	$I = k_2 t^{a_2} + i_c t$	a_2, k_2 and i_c

Where: I is cumulative infiltration (cm), *k* and *a* are Kostiakov's time coefficient terms, t is elapsed time (hour), k_1 and a_1 and *b* are Modified Kostiakov's time exponent terms (dimensionless), b is rectifying factor, S is Philip's soil water sorptivity (cm h^{-1}), A is Philip's soil water transmissivity (cm h^{-1}), k_2 and $a_2$and i_c are Kostiakov-Lewis time exponent term.

Coefficient of determination (R^2) and Root mean square error (RMSE) were used to test the goodness of fit of the four models with measured data, T-test was performed to check the effect of these amendments of the infiltration characteristics of the soil.

III. Results and Discussion

The averages of the result of analysis of soil physical properties of the study area are presented in Table 1. The results showed that the texture of the field surface (0-15cm) and the sub-surface (15-30cm) depths for the three sampled strips were predominantly sandy clay loam according to the United States Department of Agriculture (USDA) classification, having sand fraction ranging from 43-66%, silt ranging from 11-20% and clay 15-29%.

Table 2: Average soil physical characteristics of the strips

Strip	B.D(g/cm^3)	M.C(g/g)	K_s(cm/h)	%Clay	%Silt	%Sand
CM	1.53	0.06	7.37	23.2	17.8	59.0
PM	1.21	0.12	5.92	24.0	20.0	56.0
CT	1.81	0.05	4.58	26.0	14.0	60.0

*BD = Bulk density; MC =Moisture content; K_s= Saturated Hydraulic Conductivity; C = % Clay ;Si= % Silt; Sa = % Sand;

A comparison of the bulk density of the control with the other treatments shows that the application of CM and PM to the field reduced the soils bulk density by 15.5% and 33.2%, respectively. The values of saturated hydraulic conductivity ranged from 4.58-7.37 cm/h. Generally, improved soil indices were obtained in the study through the use of both amendments; however, the extent of this depends on the source of the organic manure. It was observed that poultry manure had more effect on the soils physical properties like bulk density and organic matter content although the cow dung amended strip was found to have higher saturated hydraulic conductivity values. This agrees with the result obtained by Onuh*et al.* (2008) who studied the effects of poultry Manure and cow dung on the Physical and Chemical Properties of Crude Oil Polluted Soil in Owerri, Nigeria. His findings was evidenced by the improvement in the soil physical properties.

The average results of the measured cumulative infiltration are shown in Table 3. The final infiltration rates (basic infiltration) were 7.37 cm/h for Cow dung amended strip and 5.92 cm/h for poultry litter amended strip and 4.58 cm/h for the control and these were attained after 4hours respectively.

Table 3: Average cumulative infiltration measured on the field

	Cow dung		*Poultry litter*		*Control*	
Time(hr)	*I* (cm)	*i (cm/hr)*	*I* (cm)	*i (cm/hr)*	*I*(cm)	*i (cm/hr)*
0.05	2.42	50.44	2.18	47.33	1.73	34.67
0.08	3.91	47.87	3.81	44.80	2.80	33.60
0.17	6.21	39.20	5.73	32.73	3.47	20.80
0.33	8.39	24.90	8.23	21.80	5.03	15.10
0.50	10.74	21.27	10.76	18.64	6.60	13.20
0.75	13.23	18.40	13.12	15.30	8.07	10.76
1.00	15.84	16.72	15.71	13.64	9.73	9.73
1.50	18.46	13.03	17.70	10.47	11.80	7.87
2.00	21.57	11.34	20.09	8.84	13.43	6.72
2.50	23.97	10.01	22.26	7.75	15.33	6.13
3.00	26.41	8.93	24.39	7.07	16.77	5.59
3.50	28.33	8.10	25.92	6.47	17.73	5.07
4.00	29.54	7.37	27.11	5.92	18.30	4.58

Table 3 show that the increase in the cumulative infiltration depth after 4 hours are 61.4% and 48.1% respectively. The calculated values of the t-test for CM and PM strip at a confidence level of 0.05 are 6.184 and 6.791 respectively while the critical value is 2.179. This implies that there is a significant difference and also that the incorporation of the manure affected the infiltration characteristics. Variation in the infiltration rate between the amended strip and control means that water infiltrated better into the amended soil at an average rate of 7.98 and 5.15 cm/h for CM and PM strip, Table 4 shows a variation in the estimated parameters for each strip.

Table 4: Model's parameters and modeled equations

	Kostiakov (1932)		Modified Kostiakov			Kostiakov-Lewis			Philip (1957)	
Strip	k	a	k_1	a_1	b	k_2	a_2	i_c	S	A
CM	14.826	0.546	18.361	0.6301	-1.99	5. 278	0.116	7.370	13.613	1.029
PM	14.048	0.542	17.339	0.589	-3.54	5.171	0.120	5.920	13.315	0.623
CT	9.303	0.530	9.992	0.627	-0.54	3.435	0.119	4.580	8.731	0.492

The values of fitting parameters for the infiltration models under the different land management systems obtained by regression are shown in Table 4. And Tables 5a,b and c shows the values of the predicted cumulative infiltration by the different models. The table also displays R^2 values for the regression equations, RMSE values for field-measured versus model-predicted infiltration data and equilibrium infiltration rate values for the land management systems.

Table 5a: Observed and Model predicted cumulative infiltration for CM strip

Time(hr)	Obs	KT	MK	KL	PH
0.05	2.52	2.89	3.90	4.10	3.10
0.08	3.99	3.81	5.16	4.57	4.02
0.17	6.53	5.57	7.31	5.52	5.73
0.33	8.30	8.14	10.11	7.11	8.20
0.50	10.63	10.15	12.12	8.57	10.14
0.75	13.80	12.67	14.47	10.65	12.56
1.00	16.72	14.83	16.37	12.67	14.64
1.50	19.54	18.50	19.43	16.62	18.22
2.00	22.69	21.65	21.90	20.50	21.31
2.50	25.02	24.46	24.01	24.34	24.10
3.00	26.79	27.02	25.88	28.16	26.67
3.50	28.34	29.39	27.56	31.97	29.07
4.00	29.48	31.62	29.10	35.76	31.34
	R^2	0.990	0.997	0.938	0.988
	RMSE	1.054	1.006	2.831	1.097

Table 5b: Observed and Model predicted cumulative infiltration for PM strip

Time(hr)	Obs	KT	MK	KL	PH
0.05	2.37	2.77	1.06	3.95	3.01
0.08	3.73	3.65	2.23	4.40	3.90
0.17	5.46	5.32	4.30	5.30	5.54
0.33	7.27	7.74	7.12	6.79	7.90
0.50	9.32	9.65	9.21	8.15	9.73
0.75	11.48	12.02	11.72	10.08	12.00
1.00	13.64	14.05	13.80	11.95	13.94
1.50	15.71	17.50	17.21	15.60	17.24
2.00	17.69	20.46	20.03	19.18	20.08
2.50	19.37	23.09	22.48	22.72	22.61
3.00	21.20	25.49	24.67	26.24	24.93
3.50	22.64	27.72	26.66	29.74	27.09
4.00	23.67	29.80	28.50	33.23	29.12
	R^2	0.991	0.997	0.940	0.991
	RMSE	2.875	2.393	3.823	2.533

Table 5c: Observed and Model predicted cumulative infiltration for Control

Time(hr)	Obs	KT	MK	KL	PH
0.05	1.57	1.90	2.02	1.91	1.98
0.08	2.40	2.49	2.50	1.87	2.56
0.17	3.97	3.60	3.44	2.02	3.65
0.33	6.00	5.20	4.90	2.58	5.21
0.50	7.27	6.44	6.10	3.25	6.42
0.75	9.10	7.99	7.64	4.30	7.93
1.00	10.73	9.30	9.00	5.39	9.22
1.50	12.93	11.53	11.39	7.60	11.43
2.00	14.50	13.43	13.49	9.84	13.33
2.50	16.17	15.12	15.40	12.09	15.03
3.00	17.57	16.65	17.17	14.36	16.60
3.50	18.77	18.07	18.84	16.62	18.05
4.00	19.37	19.39	20.42	18.89	19.43
	R^2	0.993	0.983	0.905	0.991
	RMSE	0.894	1.017	3.568	0.946

The R^2 ranged from 0.905 to 0.997 which are all close to unity and an indication of close agreement between the measured and predicted data for each of the infiltration models. Considering the individual performance of the models in the respective strips, the modified Kostiakov model performed better in the CM and PM strip with R^2 values of 0.997 while the Kostiakov's R^2 value was the best for control strip.

The result of RMSE shows that Modified Kostiakov's model had the least error in comparing the predicted values with field measured values followed by Philip's model for the Control, Cow dung and Poultry litter amended strip.

Gana (2011) studied the effect of cow dung on soil with higher sand percentage in Bida, Niger state, the effect of cow dung was not significant and also showed that cow dung with inorganic fertilizer cannot easily influence the soil texture. However, according to Gupta *et al.* (2004) application of cow dung helps in improving soil structure, soil aeration and therefore improves the activities of soil micro-organisms.

Odofin (2012) showed that Kostiakov, modified Kostiakov and Philip infiltration models were all found to be suitable for simulating water infiltration into an Alfisol subjected to untilled mulched, tilled-mulched and tilled-unmulched management systems at Minna, Nigeria. However, modified Kostiakov model simulated water infiltration more accurately than Philip model while classical Kostiakov model was the least accurate. Infiltration data from highly permeable soils under five different land use histories on Nsukka plains of south-eastern Nigeria showed that either the modified Kostiakov model or modified Philip model could be used for routine characterization of the infiltration process (Mbagwu, 1995). The Kostiakov and modified Kostiakov equations tend to be the preferred models used for irrigation infiltration, probably because it is less restrictive as to the mode of water application than some other models.

IV. Conclusions

The application of 50 kg of organic manure to 0.004 ha (40 m^2) increased the steady state infiltration by an average rate of 7.98 and 5.15 cm/h for CM and PM strip respectively and also the cumulative infiltration depth increased by 61.4% and 48.1% for CM and PM strip, also the soil properties where improved accordingly. The models provided good overall agreement with the field measured cumulative infiltration depths and are therefore capable of simulating infiltration under the field conditions in this study. T-test showed a significant difference between the amended strip and the control, the water holding capacity also increased by 11.8% and 13.9% for CM and PM strips respectively. Similar work can be carried out to study the effect of different application rate of organic manure on the infiltration capacity and soil physical properties of the amended soils.

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